Thomas-Fermi Fission Barriers*

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Using the self-consistent Thomas-Fermi model from our earlier work, backed by the liquid-drop-model scaling rule for fission barriers, we have constructed a simple algebraic equation for Thomas-Fermi fission barriers. This has made it possible to make a comprehensive comparison of the Thomas-Fermi theory with 120 measured fission barriers.

Calculated barriers were fitted by the following formula:

$$B(N,Z) = S(N,Z)F(X) \ \text{MeV}, \qquad (1)$$

where S, approximately proportional to the nominal surface energy of a nucleus, is given by

$$S = A^{2/3}(1 - kI^2) \ , \qquad (2)$$

with $I \equiv (N-Z)/A$, and with k, the "surface symmetry coefficient", taken to be the following function of Z:

$$k = 1.9 + (Z - 80)/75 \ . \qquad (3)$$

The fissility X is proportional to the ratio of the nominal Coulomb and surface energies of a sphere:

$$X = Z^2/A(1 - kI^2) \ . \qquad (4)$$

The function F is a cubic joined smoothly to a straight line at $X = X_1$:

$$F(X) = 0.000199749(X_0 - X)^3 \qquad (5)$$

for

$$X_1 \leq X \leq X_0 \qquad (6)$$

and

$$F(X) = 0.595553 - 0.124136(X - X_1) \qquad (7)$$

for

$$30 \leq X \leq X_1 \ , \qquad (8)$$

with $X_0 = 48.5428$ and $X_1 = 34.15$. (The conventional fissility parameter x corresponds approximately to X/X_0).

The form of Eq. (1) was suggested by the Liquid Drop model (a first order approximation to a Thomas-Fermi model [2]), for which the fission barrier in units of the surface energy is a standard function of the fissility. This Liquid Drop scaling was found to work very well also for the Thomas-Fermi model.

The transition of the function $F(X)$ from a cubic to a more nearly linear function of X (at $X_1 = 34.15$) is also a familiar feature of the Liquid Drop model. It is associated with the fairly rapid transition from cylinder-like to hour-glass-like saddle-point shapes that takes place near the above value of the fissility [3].

The study of nuclei under extreme conditions of spin, isospin, temperature and deformation is likely to continue to be a theme of nuclear physics in the coming years. Fission studies allow one to examine the most extreme nuclear deformations, namely the saddle point shapes defining the fission barriers. These shapes vary from cylinders with rounded ends in the mass region $A = 250$, to moderately necked-in shapes near $A = 200$, to hour-glass figures for still lower mass numbers. Thus fission studies provide information on nuclear shapes that include and even go beyond so-called hyperdeformations. The macroscopic description of these shapes and barriers, based on a well-founded, self-consistent Thomas-Fermi theory of nuclei, should be useful in illuminating the physics of these exotic nuclear configurations.

*Extracted from Ref. [1]

[1] W.D. Myers and W.J. Świątecki, Phys. Rev. **C60**, 014606 (1998).

[2] W.D. Myers and W.J. Świątecki, Ann. Phys.(N.Y.) **55**, 395 (1969).

[3] W.J. Świątecki, Phys. Rev. **104**, 993 (1956).